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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

**USING SIMULATION ANALYSIS TO EVALUATE
ENLISTMENT PROGRAMS FOR NON PRIOR SERVICE
ARMY RESERVE ENLISTMENTS**

by

Anne C. Bailey

June 2010

Thesis Advisor:
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**USING SIMULATION ANALYSIS TO EVALUATE ENLISTMENT PROGRAMS
FOR NON PRIOR SERVICE ARMY RESERVE ENLISTMENTS**

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Submitted in partial fulfillment of the
requirements for the degree of

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from the

**NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

The United States Army Reserve (USAR) currently has two enlistment program options—the Delayed Training Program (DTP) and the Delayed Entry Program (DEP). Enlistments under the DTP are counted as immediate gains and increase the count of the USAR end strength, while enlistments into the DEP do not increase the end strength until the Soldier ships to Basic Combat Training (BCT). Historically, these two programs have not been offered concurrently. Due to recent fluctuations in the USAR end strength, a need has been identified for these programs to operate simultaneously. This thesis develops a simulation model that allows the study of the mix of applicants allowed to enlist under the DTP or DEP. The simulation illustrates that under current operating conditions applicants who are in high school or on an alternate training path, as well as 17%–25% of the remaining population of applicants should enlist under the DEP. This policy stabilizes the USAR end strength. The simulation model developed in this thesis can be used to test alternate policies for guiding enlistments as fluctuations in factors such as enlistment rate and attrition rate occur.

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LIST OF ACRONYMS AND ABBREVIATIONS

AIT	Advanced Individual Training
ALT	Alternate Trainer
BCT	Basic Combat Training
CIHS	Currently in High School
DEP	Delayed Entry Program
DMOSQ	Duty Military Occupational Specialty Qualified
DTP	Delayed Training Program
ELIM	Enlisted Loss Inventory Model
ESO	End Strength Obligation
FY	Fiscal Year
JSOMS	Joint Specialty Officer Modeling System
MEPS	Military Entrance Processing Station
MLRPS	Manpower Long Range Planning System
MOS	Military Occupational Specialty
MOSLS	Military Occupational Specialty Level System
NDAA	National Defense Authorization Act
NPS	Non-Prior Service
P-B	Plackett-Burman
PS	Prior Service
USAR	United States Army Reserve

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EXECUTIVE SUMMARY

The United States Army Reserve (USAR) end strength has reported drastic fluctuation from the End Strength Obligation (ESO) authorized by Congress over the past 10 years. One element to maintaining ESO is managing accessions and retention. The USAR currently has two Non-Prior Service (NPS) enlistment program options—the Delayed Training Program (DTP) and the Delayed Entry Program (DEP). Enlistments under the DTP are counted as immediate gains and increase the count of the USAR end strength, while enlistments into the DEP do not increase the end strength. Historically, these two programs have not been offered concurrently. Due to the most recent fluctuations in the USAR end strength, a need has been identified for these programs to operate simultaneously.

This thesis develops a simulation model used to study different enlistment policies. Although there are two portions to the model, Prior Service (PS) and NPS, the only portion manipulated during this study was the NPS portion. This portion simulates applicants from the time they arrive at the MEPS to the time they ship to Basic Combat Training (BCT).

Historical data was evaluated to determine attrition rates, length of time in service before attrition, and length of time in service prior to shipment to BCT. The simulation model takes these and other factors such as the percentage of applicants allowed to join the DEP into account. Twenty-one factors are manipulated during experiments on the simulation. These experiments are used to relate the 21 factors to end strength.

Results of the simulation illustrate that under current operating conditions applicants who are in high school or on an alternate training path and 17%–25% of the remaining population of applicants should enlist under the DEP in order to maintain end strength below 209,100. The simulation model developed in this thesis can be used to test alternate policies for guiding enlistments as fluctuations in factors such as enlistment rate and attrition rate occur.

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I. INTRODUCTION

A. BACKGROUND

Title 10, United States Code (“Personnel Strengths: Requirement for Annual Authorization|LII/Legal Information Institute”), provides the authority for personnel strengths for each of the services. The National Defense Authorization Act (NDAA) (National Defense Authorization Act for Fiscal Year 2010) prescribes the number of personnel authorized. This number may change from year to year based upon budget and troop requirements. The End Strength Obligation (ESO) is required to be met on 30 September of each year. The ESO for the United States Army Reserve (USAR) during Fiscal Year (FY) 2010 is 205,000 Soldiers. The NDAA authorizes the Secretary of the Army to allow for a 2% increase from the ESO, which brings the maximum end strength authorization to 209,100 Soldiers.

A key element in reaching and maintaining ESO authorizations for any service is managing accessions and retention. Historically, when Non-Prior Service (NPS) applicants enlist in the USAR, they were immediately counted against end strength and enlisted under the Delayed Training Program (DTP). The USAR adopted the Active Component enlistment program called the Delayed Entry Program (DEP) in 2004, which prevents a new enlistee from immediately counting against the end strength. This change was made in order to temporarily decrease the USAR End Strength.

The DEP was developed to manage end strength. While the DEP has historically served as a regulation for ESO, there are no set rules or guidelines about when an enlisted application should fall under this program. This thesis is aimed at studying accession and retention related factors in order to help develop guidelines for accessing enlistments into the DTP rather than the DEP. A brief overview of the two programs and the history of their use follow.

1. Delayed Training Program Overview

The DTP is a method of accounting for Soldiers awaiting shipment to Basic Combat Training (BCT). The USAR uses this program in order to allow new enlistees to

be integrated into their units prior to BCT. The difference between the USAR and the Regular Army is that when applicants enlist into the USAR, they know exactly which unit they are assigned, in contrast to the regular Army enlistees who do not have this information until later in their training path.

Enlistments into the DTP are immediate gains to the USAR, and are assigned to a unit against a vacancy. Although these Soldiers boost the end strength of the USAR, they are not qualified for the position until they complete their training within the subsequent 48 months. This is viewed as a drawback. To monitor this, the USAR maintains the unit Duty Military Occupational Specialty Qualified (DMOSQ) measure to reflect the readiness level for each unit's assigned personnel; the new Soldier that is in the DTP is counted as non-DMOSQ. Soldiers are considered non-DMOSQ until they complete Advanced Individual Training (AIT). Non-DMOSQ Soldiers are viewed as decreasing the readiness rating of the unit.

Soldiers who are on a standard training path attend BCT for approximately nine weeks and then ship directly to AIT. AIT schools last anywhere from 2–12 months, depending on the Military Occupational Specialty (MOS) in which the Soldiers have enlisted. For example, AIT for a 42A, Human Resources Specialist, is just over eight weeks while AIT for a 68A, Biomedical Equipment Specialist, is 41 weeks long. Soldiers who do not ship directly from BCT to AIT are placed on an alternate training path and are considered “split option trainers.” These Soldiers are normally attending high school or college and are only able to attend BCT and AIT during the summer months when they are on break from their degree programs.

New enlistees in the DTP may attend and get paid for up to 36 Unit Training Assemblies per year, for up to two years, in the DTP while awaiting BCT. A Unit Training Assembly is a four-hour block during which the Soldier is present for duty; this is also referred to as drill. A normal duty weekend for a Reserve Soldier consists of four 4-hour blocks of duty. When a Soldier is present for duty, he or she is also earning retirement points for their service.

The cost to the USAR for DTP Soldiers attending drills and earning retirement points while simultaneously decreasing readiness can be viewed negatively. Some of these Soldiers are subsequently discharged after receiving these benefits even though they were never qualified for their position. The DEP does not incur these costs, but reduces the end strength. The DEP is discussed next.

2. Delayed Entry Program Overview

Enlistments into the DEP are different because they are not counted against USAR end strength, and are not allowed to attend or get paid for drill. Since they are not assigned against a unit vacancy, they do not degrade the unit readiness by being non-DMOSQ. They do not become a member of the USAR or count against the end strength until shipment to BCT.

When applicants enlist into the DEP, they are immediately assigned to the Individual Ready Reserve and a BCT training seat is reserved for them. The Individual Ready Reserve is a manpower tool used to account for Soldiers who have completed their contractual obligation, but not their military service obligation. There is also a special provision in the Individual Ready Reserve that accounts for enlistees who are awaiting BCT (Rotsker). The time between when applicants enlist and the time they ship to BCT is anywhere from 1–365 days. While an applicant is in the DEP, he or she has no military obligation other than to stay out of trouble, stay fit, remain within the weight restrictions, and return to the Military Entrance Processing Station (MEPS) when directed for shipping to BCT.

3. History of Delayed Training Program and Delayed Entry Program

Until FY 2004, all applicants enlisting into the USAR entered in the DTP. At the end of FY 2003, the USAR end strength exceeded 211,000, which is approximately 2,000 above the maximum authorized end strength. Because of this excess of personnel, the Chief, Army Reserve implemented the DEP in 2004 in order to reduce end strength numbers and comply with the authorized range. Thus, FY 2004 was a year of transition as enlistments were switched from the DTP to the DEP. The transition from DTP to DEP occurred based on which recruiting brigade an applicant enlisted through. The recruiting

brigades were to begin enlisting applicants into the DEP in three phases: Phase I, 2d Recruiting Brigade; Phase II, 5th and 6th Recruiting Brigades; and Phase III, 1st and 3d Recruiting Brigades. Beginning with Phase I, enlistments into vacancies in the designated recruiting brigades' area of operation were into the DEP while the other brigades' remained DTP enlistments. With each phase, the additional brigades began enlisting into the DEP until all three phases were complete. In addition to bringing the end strength to an authorized level, this transition also prevented a decrease in readiness in the USAR since the new enlistees were not counted as DMOSQ numbers. Figure 1 shows the years the DTP and DEP policies were in use.

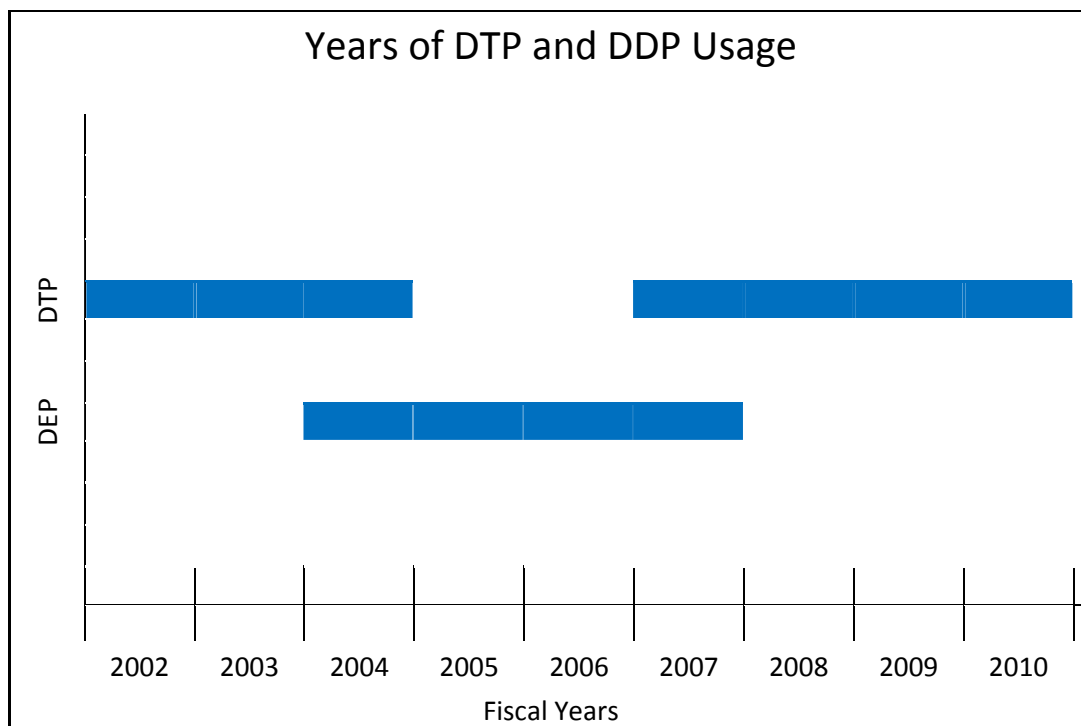


Figure 1. Fiscal Years the DTP and DEP Were in Effect

After 2004, the USAR experienced a drastic decrease in end strength numbers. While some decline was expected since the non-DMOSQ Soldiers in the DTP were eliminated, there was also decline due to difficulty finding volunteers to enlist. The change in the recruiting market adversely impacted recruiting for not only the Army Reserve, but also the Active Component and the Army National Guard.

In FYs 2005 and 2006, the USAR had extreme shortages of personnel and fell short of the authorized end strength by about 15,000 Soldiers. This sharp decrease is depicted in Figure 2, which illustrates a time series plot of USAR end strength from 2003 to 2009. Because of this shortage, the Chief, Army Reserve decided to return to the DTP in May 2007 in an effort to increase the end strength of the USAR. This was one of several initiatives implemented to boost USAR end strength. The end of year strength trend line shows the drastic drop in end strength in 2004–2005 when the USAR transitioned to the DEP. It showed a significant increase between 2007 and 2009, when the USAR returned to the DTP.

Other initiatives to boost end strength included the implementation of the Critical Skills Retention Bonus—Army Reserve (Boggess), which targeted retention of captains assigned to specific branches, such as Chaplains; implementation of the Army Reserve—Recruiter Assistance Program, an initiative that motivates all Soldiers to recruit by paying them \$2,000 for each applicant they enlist (with the condition that the applicant must complete AIT); and increasing enlistment bonus for all NPS applicants to the maximum authorized by law.

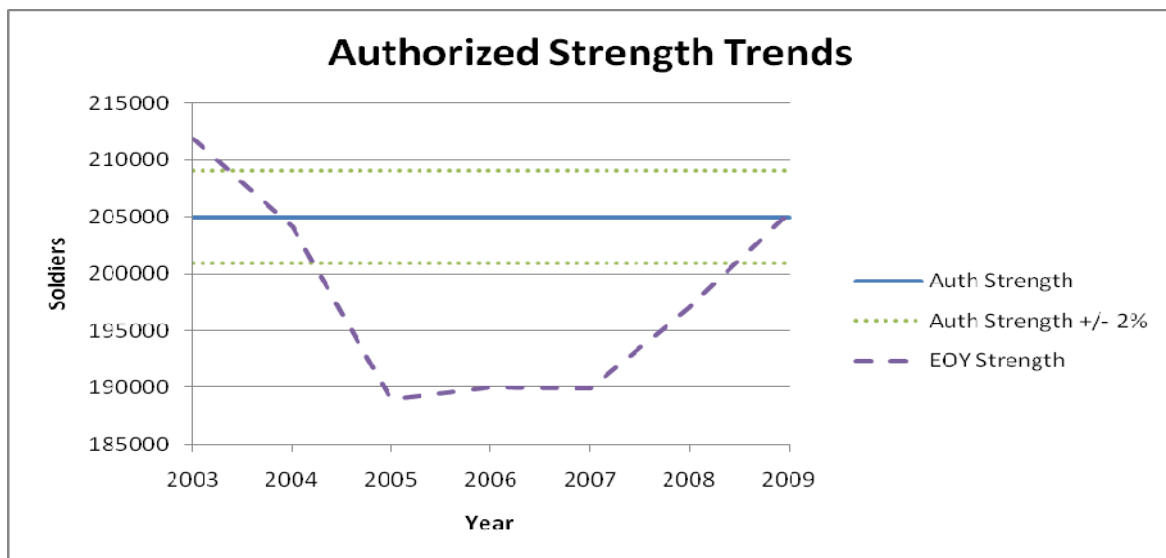


Figure 2. Authorized Strength Levels by Year

When the USAR changed from the DEP to the DTP in 2007, the end strength increased quickly. Two years after reinstating the DTP, the end strength numbers were

not only met, but reached the 2% over ESO and the USAR had to stop enlisting Soldiers into non-critical MOS in June 2009. As a result of ceasing enlistments for the last three months of FY09, the USAR only enlisted 370 applicants (into critical MOS), as can be seen in Figure 3. The normal average for a three-month period is just over 4,000 enlistments, or approximately 1,400 per month.

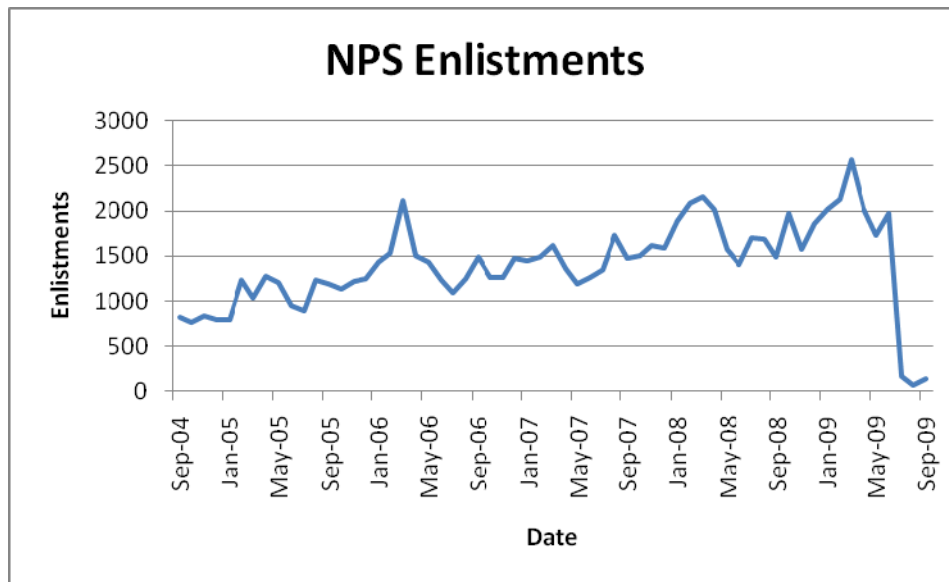


Figure 3. Time Series Plot of Number of Non Prior Service (NPS) Enlistments per Month

The stopping of enlistments is detrimental not only to recruiting momentum, but also to the quality of the enlistees. Because the USAR is still under the policy that states that enlistments fall under the DTP (Stultz), it is cautious about the number of applicants allowed to enlist to ensure that the maximum authorized end strength is not exceeded. Although end strength numbers were at the maximum authorized level from July through September 2009, unit readiness suffered because many of these applicants were in units, but were non-DMOSQ.

Regardless of which program applicants enlist under, they are assigned an MOS and a training seat for BCT is reserved for them. If they are on a standard training path, meaning they ship directly from BCT to AIT, they are also scheduled for an AIT seat. Members of the DTP or DEP who do not ship to BCT are considered a loss. Enlistees

fail to ship to BCT for various reasons, including fraudulent enlistment, pregnancy, testing positive for illegal drug use, and failure to meet the weight standard. These losses are costly in both time and money.

When a Soldier becomes a loss from the DTP, the unit is responsible for the loss and that enlistment may not be regained, meaning the unit is required to recruit a new enlistee to replace the one that is lost. Recruitment for the USAR is conducted both by recruiters and Soldiers within units. These Soldiers interact with the public regularly and are able to entice fully qualified applicants to fill vacancies within their units. When an applicant becomes a DEP loss, recruiters are responsible for enlisting another qualified applicant, which makes their job increasingly difficult. Depending on when the enlistee becomes a loss, the training seat they were holding may go unfilled. Training seats are costly and must be paid for by the USAR whether or not a Soldier fills that training seat.

Because enlistments have gone into DTP during some time periods and into DEP in others, USAR end strength has not been consistent. This thesis studies utilizing a combination of both policies rather than the historical either/or policies that have failed to regulate end strength.

This thesis develops a simulation model of the accessions and retention in the USAR in order to study the effect of DTP versus DEP enlistment and its impact on end strength. The results help guide the USAR in determining which program applicants should enlist under, with the goal of maintaining consistent end strength at the authorized number of Soldiers.

B. OBJECTIVE OF THESIS

The objective of this thesis work is to create a simulation model that is easily adjusted to run various scenarios to evaluate policy decisions that specify when applicants should enlist into the DTP or DEP. This thesis describes the development of a simulation of the enlistment process as well as an analysis of factors that influence end strength. This research also attempts to identify a mix of applicants entering the USAR under the DTP versus DEP that allow regulation of end strength.

C. LITERATURE REVIEW

One of the main concerns of the Army is manpower, or more specifically, strength management, which is putting the right Soldier in the right unit in order to accomplish the mission. There have been several studies conducted on manpower and manpower modeling, most of which utilized optimization models. These models deal primarily with active component manpower and how individuals progress through their military career.

Edwards (1031-1040) discusses the need for models in manpower planning and reviews several different types of Department of Defense models. These models included deterministic and stochastic models. He determined that models that use aggregate numbers are more widely used than those that consider individuals specifically. Throughout his survey process, he determined that simulation models appear to be used less often due to data requirements.

Much as Edwards does, Schank et al. (17–24), discuss that strength management models have a varying range of complexity. The less complex models utilize the basic formula for determining future strength: $\text{Future Strength} = \text{Current Strength} + \text{Gains} - \text{Losses}$. More complex models include one or two additional variables, for example, years of service or term of enlistment. The most complex models include even more variables, such as rank structure and MOS breakdown. The Army uses two models, the Enlisted Loss Inventory Model (ELIM) and the Military Occupational Specialty Level System (MOSLS), in order to minimize the deviations from the operating strength, which is the difference between the number of authorizations and the people available to fill those authorizations. Both of these models optimize and simulate. They “integrate accession, retention, training, promotion, and reclassification policies and organizations by providing an integrated framework for addressing near-term programming adjustments and long-term policy guidance” (Schank et al. 23).

MOSLS is described in more detail and reviewed in an article published by Eiger et al. (57-73). MOSLS creates a seven-year projection of the Army’s enlisted strength by rank and MOS. MOSLS seeks to place Soldiers into positions for which they are fully

qualified. Soldiers assigned to positions they are not trained for are considered misaligned. MOSLS also conducts a cost-benefit analysis based on misaligned Soldiers. In addition to the optimization and simulation models within MOSLS, there is also a network model that works with a Markovian process modeling MOS transfers, promotions, gains, and losses. The projection system of MOSLS is a “multi-period network model of personnel flow within the enlisted ranks” (Eiger 64). Arcs in the network represent personnel flows. “Some of these arcs have negative costs (incentives) to represent flow below the target, and some positive. Thus we say that MOSLS’ optimization is based on separable linear goal programming” (Eiger 64). The simulation portion of the model interprets the solution provided by the optimization to more accurately portray losses and promotions. In their review of MOSLS, Eiger et al. (57–73), determined that in using MOSLS, the Army saved over \$65 million in annual benefits in 1986 by correctly aligning the non-commissioned officer positions.

The United States Army Manpower Analysis Agency published a document in June 2008 outlining the manpower modeling methods used by the U.S. Army to determine manpower requirements. The document describes the five steps used in creating a manpower model. These steps include selecting the function (formulate the problem), analyze business processes (evaluate how operations are currently conducted), select potential approaches, formulate models and simulations (create the model), and validate models and simulations. It goes on to state that once these five steps have been completed, the model should be “verified, validated, and approved for use. If the analysis team utilized foresight enough to make a flexible tool, then the tool can be used beyond the traditional manpower requirements determination. It can be used at many levels for sensitivity analyses, organizational efficiency assessments, and process improvement studies. Again, the model and its commensurate simulations are tools that can have more than one use” (U.S. Army 8). When the process outlined in this document is complete, the Army “will have a powerful analytical tool at its disposal to enable leadership at several levels to make informed decisions” (U.S. Army 9).

Gass et al. (5–17) discuss the Army Manpower Long Range Planning System (MLRPS). MLRPS uses a stochastic model to project the strength of the Army over a

20-year period, breaking it down into skill, years of service, and rank level detail. It allows for projections of strength, gains, losses, and movement from one MOS to another. It also uses a linear goal programming formulation in order to determine transition rates. MLRPS, like other models discussed in this section, looks to put the correct person in the correct position.

The Joint Specialty Officer Modeling System (JSOMS), as discussed by Hentzchel, is “a management tool capable of analyzing the immediate and long-term impact of joint policy implementation” (vii). JSOMS simulates the assignment process for naval officers. Much like MLRPS, this model also accounts for gains, losses, promotions and rotations. However, JSOMS operates on a quarterly clock instead of the annual clock of the MLRPS. The development of the JSOMS included three types of approaches: (1) array transition modeling, (2) network simulation, and (3) discrete entity simulation. Because discrete entity simulation was the only approach that proved effective, it was ultimately used to build the JSOMS. It considers each officer individually as they move through their military career.

Common methods used in manpower modeling include optimization and simulation. Optimization models use aggregate numbers as opposed to specific individuals, which may be why they are used more frequently. They have fewer data requirements than simulation models and are good for determining the deviation from operating strength. Simulations follow individuals throughout the system, which gives a better portrayal of behavior. Simulations are good for viewing policy changes, but are not highly used due to the data requirements.

D. THESIS ORGANIZATION

Chapter II provides a description of the discrete event simulation model that is built for the research presented in this thesis. Chapter III discusses the experimental design that is used to study the simulation model. Chapter IV provides an analysis of the model, which is done through design of experiments and statistical data analysis of the results from the experiments conducted using the simulation model. Chapter V provides conclusions and recommendations.

II. METHODOLOGY

This chapter discusses the development of the simulation model including the historical data used to create inputs to the model. It also discusses how the data is used to validate the simulation model, the scope and limitations of the model, and assumptions used in the model.

A. BUILDING OF A DEP/DTP POLICY SIMULATION MODEL

An Arena simulation model (Arena®) is created in order to review different enlistment policies for this thesis. It acts as a decision analysis tool that can be used to suggest what percentage of applicants should be allowed to enter the USAR in the DTP, rather than the DEP, to maintain ESO. There are two main portions of the Arena model, the Prior Service (PS) portion and the NPS portion. The high level model is shown in Figure 4.

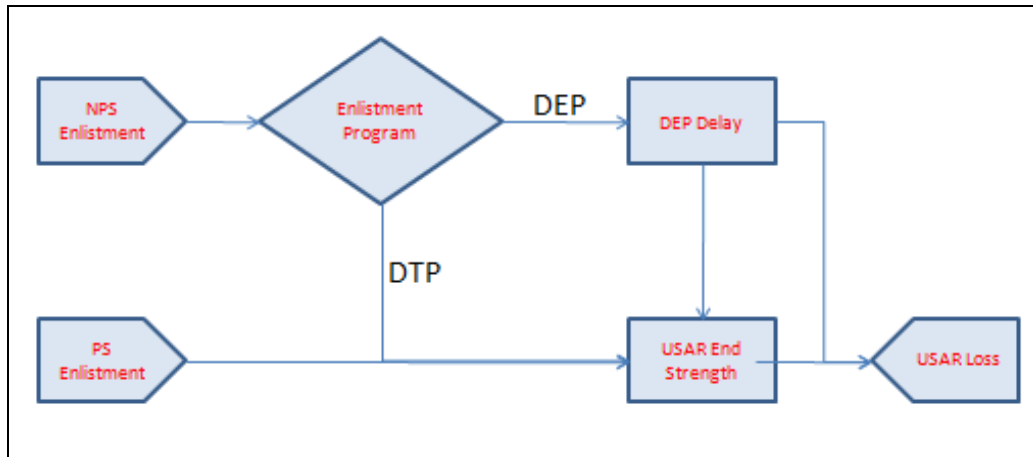


Figure 4. High Level Overview of Simulation Model

The PS portion, Figure 5, depicts the portion of the model that contains Soldiers enlisting or transferring to the USAR who have had more than 180 days of military service (Army Regulation 601-210 17). These Soldiers may come directly from the Active Component, the Individual Ready Reserve, or have completed their initial term of service and then have decided to enlist in the USAR after a break in service.

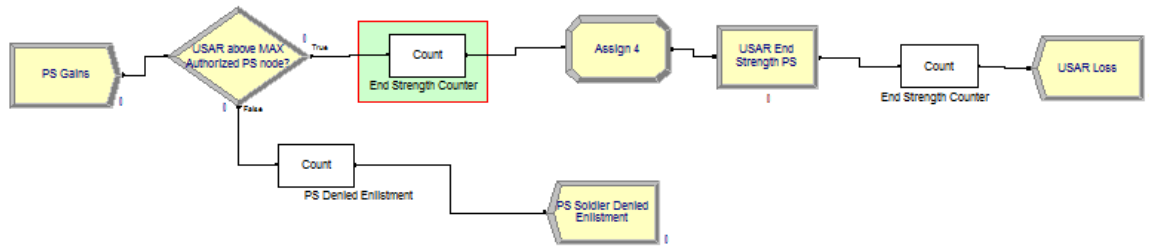


Figure 5. PS Portion of Arena Model

This section of the model simulates a PS Soldier from the time he or she enters the USAR to the time he or she leaves the USAR, and is counted against the end strength of the USAR from the date of the enlistment contract to the date of the expiration term of service. The model conducts a check of end strength upon the arrival of a potential PS enlistment to ensure the USAR is not above the authorized strength. If the end strength is not at the maximum authorized level, the Soldier is allowed to enlist. Soldiers remain in the system for a designated amount of time based on historical data. Once they reach that designated length of time, they become a loss to the USAR.

The NPS portion of the model, which is the focus of this thesis, simulates applicants enlisting for the first time into the USAR. The initial portion of the model is in Figure 6. Not all fully qualified applicants who arrive at the MEPS enlist. This is accounted for early on and those applicants leave the model with no further processing. Much as with the PS portion of the model, when an applicant decides to enlist, a check of the end strength is conducted and if the USAR is at the maximum capacity, that applicant is denied enlistment. This mirrors what occurred in June 2009 when enlistments stopped.

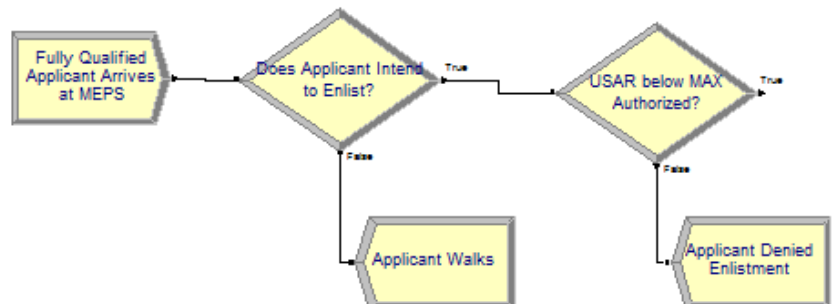


Figure 6. Initial NPS Portion of Arena Model

Applicants who are allowed to enlist then proceed through the remainder of the model, following a path depending on what category they are assigned. NPS applicants are separated into three categories: (1) Currently in High School (CIHS); (2) Alternate Trainer (ALT); or (3) Applicants who do not fall into previous two categories (OTHER). The CIHS applicants are juniors in high school who do not ship to BCT until the end of their junior year. ALT applicants enlist under the DTP or DEP for up to a year prior to shipment to BCT. The USAR has a maximum number of CIHS and ALT enlistments authorized each year as determined by the annual mission letter (Farrisee), which is a document that prescribes the accession mission or goal for that fiscal year. The largest of the three categories is the OTHER category, which simulates enlisting under DTP or DEP based on proportions set by the user. This category has the most potential to impact end strength.

The NPS portion of the model simulates the arrival of a fully qualified applicant at the MEPS through the time he or she ships to BCT. It models the fraction of fully qualified applicants who actually contract, those who enter the DTP and DEP, the percent that fail to ship to BCT, and the time they are in the USAR if they do fail to ship to BCT. In addition, it also simulates the amount of time they are in the DTP or DEP before they ship to BCT.

Neither portion, PS nor NPS, of the model allows enlistment if the USAR end strength is above the maximum authorized by Congress. When end strength exceeds authorizations, the USAR will deny all applicants, including those fully qualified, from joining the USAR. Figure 7 shows the remainder of the NPS model that extends from Figure 6.

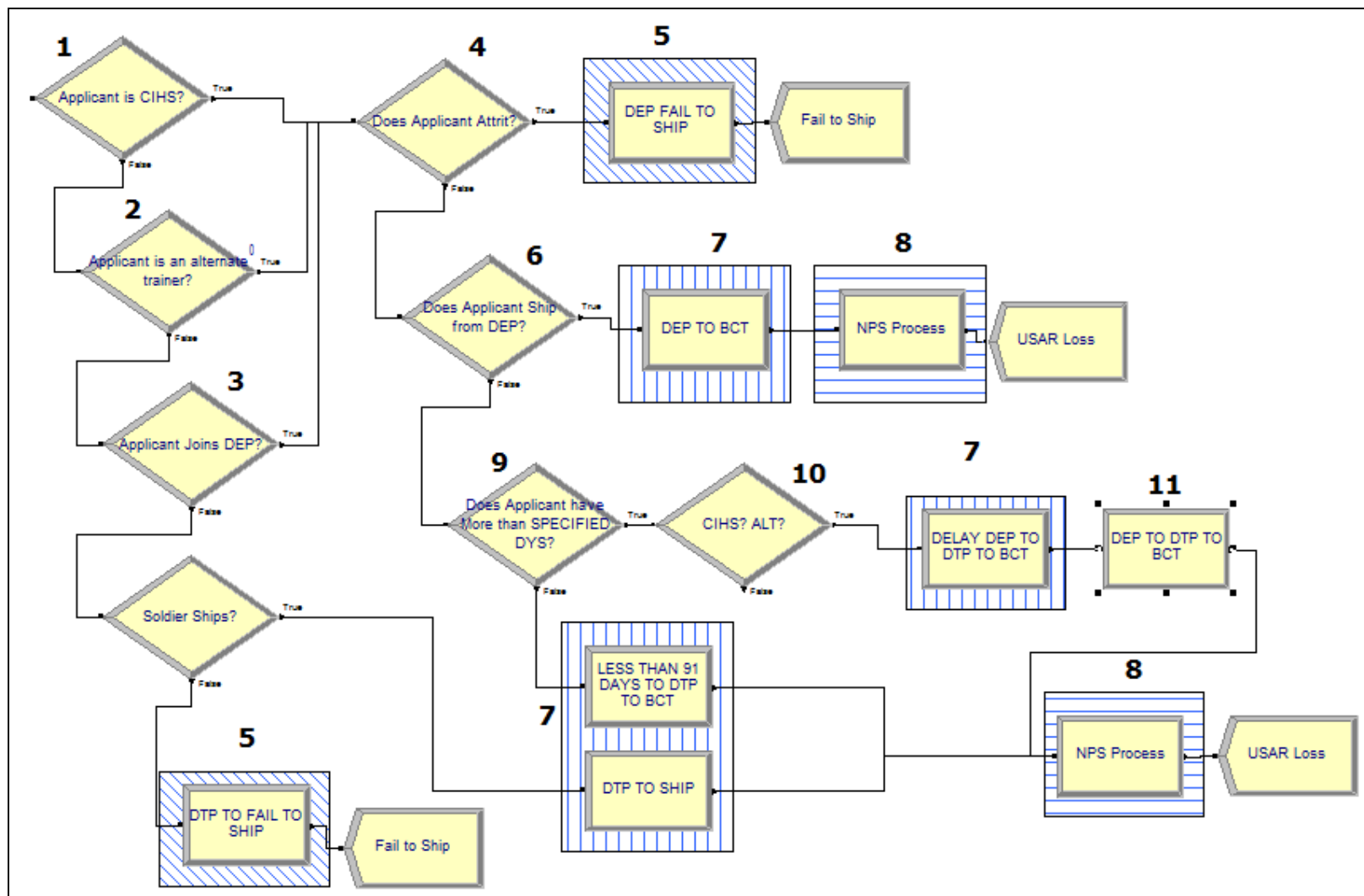


Figure 7. Main NPS Portion of Arena Model

The nodes are labeled and a description follows. The shaded nodes represent blocks of the simulation that perform the same task.

- Nodes 1 and 2: Assignments to CIHS, ALT, or OTHER, based on proportions of the total population.
- Node 3: Percent of OTHER who join enlist under the DEP.
- Node 4: Enlistments under the DEP who fail to ship to BCT.
- Node 5: Time the enlistee is in the DTP or DEP prior to failing to ship to BCT.
- Node 6: Percent of enlistees who ship to BCT directly from DEP.
- Node 7: Time the enlistee is in the DTP or DEP prior to shipment to BCT.
- Node 8: Time Soldier is in the USAR before they exit the service.
- Nodes 9–11: Accounts for enlistments under the DEP that transfer to DTP for a specified amount of time prior to BCT.

B. DATA COLLECTION RESOURCE

The data used in this thesis was collected from two agencies, the United States Army Recruiting Command and the Army Reserve G1; see Table 1.

DATA	RESOURCE
LOSS DATA PRIOR TO BCT	USAREC
ACCESSION	ARMY RESERVE G1
LENGTH OF SERVICE	ARMY RESERVE G1

Table 1. Data Provider

The data was processed and used in the simulation. The data analysis consisted of determining proper distributions to fit the data. The distributions are used in simulation as representations of reality. For example, consider the distribution of ALT applicants who attrit before BCT. The author filtered this data from all those who attrit before BCT.

This data is then analyzed using the Arena Input Analyzer (Arena®). The Arena Input Analyzer pulls data from a text file and determines the maximum likelihood estimators for various distributions. It then calculates the mean squared error and rank orders those distributions from smallest to largest mean squared error. The author then conducted Chi-Squared goodness of fit tests on the three best ranked distributions. This step tests the null hypotheses that the data came from each of these distributions. There were 14 data sets tested in which the corresponding p-values failed the goodness of fit tests. Empirical distribution functions were then used to model the inputs, a process which is plausible for large data sets.

Figure 8 shows the empirical cumulative distribution of the number of days ALT applicants spend in the DEP before they attrit (prior to BCT). The numbers on the y-axis show the cumulative probability (numbers above the bars on the graph) that applicants remain in the DEP a certain number of days (x-axis) before they attrit (prior to BCT). For example, 5.8% of enlistees spend 31 days or less in the DEP before they attrit (prior to BCT).

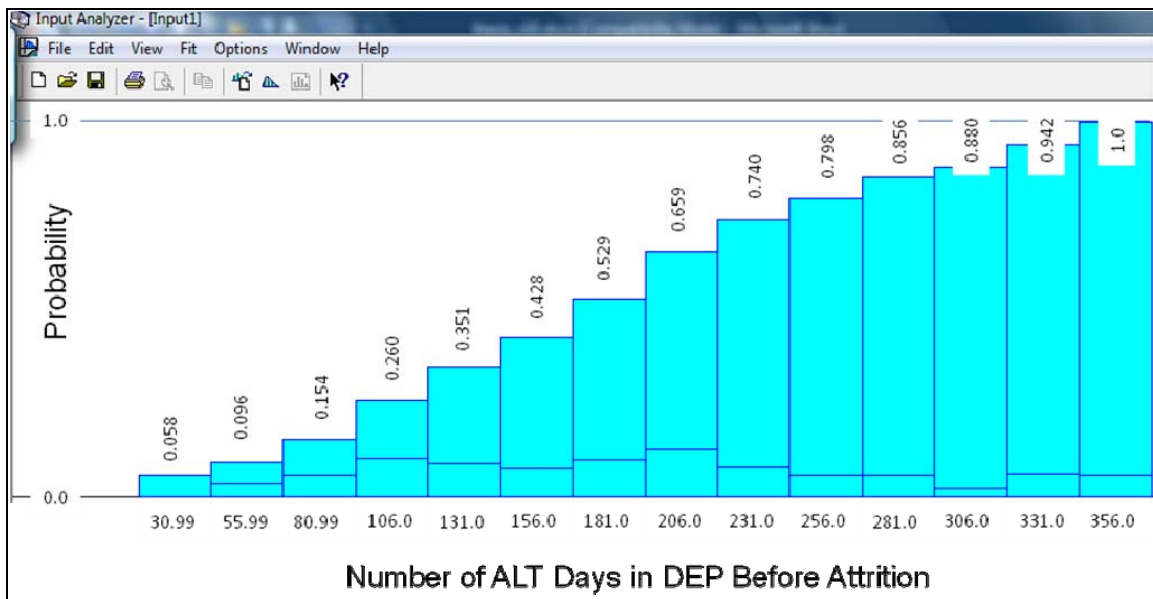


Figure 8. Input Analyzer (Arena®) Empirical Cumulative Distribution of ALT Days in DEP before Attrition

Data provided from United States Army Recruiting Command includes loss data on enlistments that occurred between FY2005 and FY2009. This data provided the date the applicant contracted (enlisted) into the USAR, the date the applicant was scheduled to ship to BCT, and the date the applicant became a loss to the USAR. The data also provided various attributes of the applicants such as their education level and training path. This data enabled the author to conduct analysis on two years of data for both the DTP (FY 2008-FY 2009) and DEP (FY 2005-FY 2006). Because FY 2004 and FY 2007 were transition years, they were not used for the analysis of attrition from DTP or DEP, or length in each program prior to shipping to BCT or failing to ship.

Accession data from FY 2000-FY 2009 was provided by Army Reserve G1. This data includes daily gains (accessions) of all PS, NPS, Officer, Warrant Officer, and Enlisted categories. Because FY 2009 was not a normal year for enlistments and enlistments were almost completely shut down for the last three months of the fiscal year, it was not used when determining accession rates into the USAR. Army Reserve G1 also provided monthly loss data and length of service for these same categories. Figure 9 depicts the gains and losses for the USAR from FY 2000 to FY 2009. As can be seen in this figure, one cause leading to the USAR reaching the maximum authorized end strength is that in FY 2008 and FY 2009 the gains outnumbered the losses.

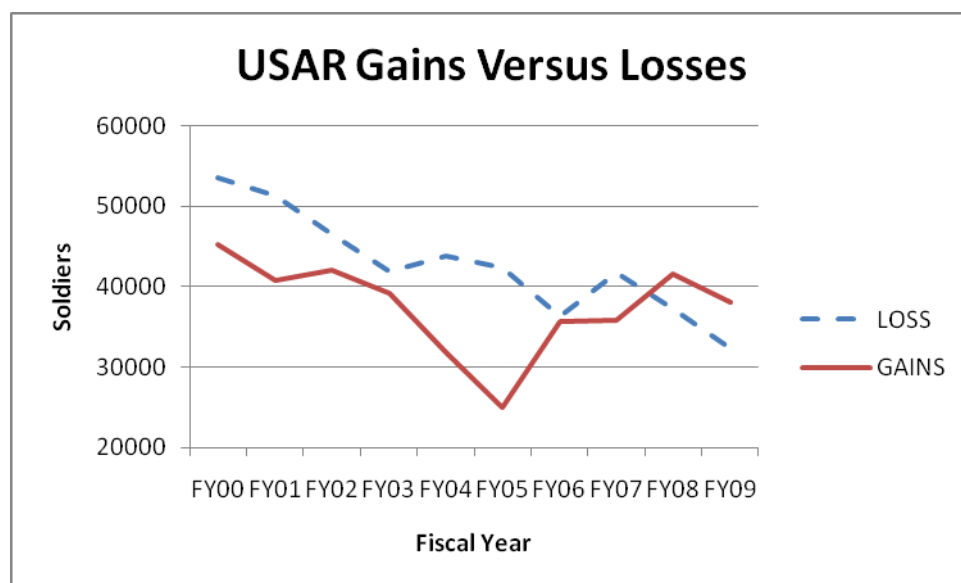


Figure 9. USAR Gains Versus Losses

C. MODEL VERIFICATION AND VALIDATION

The simulation model is verified with debugging and the use of animation. The simulation model is created in steps and debugged after each step prior to creating the next portion of the model. Each applicant was animated and watched as it progressed through the model to ensure it traveled through the model in the correct manner.

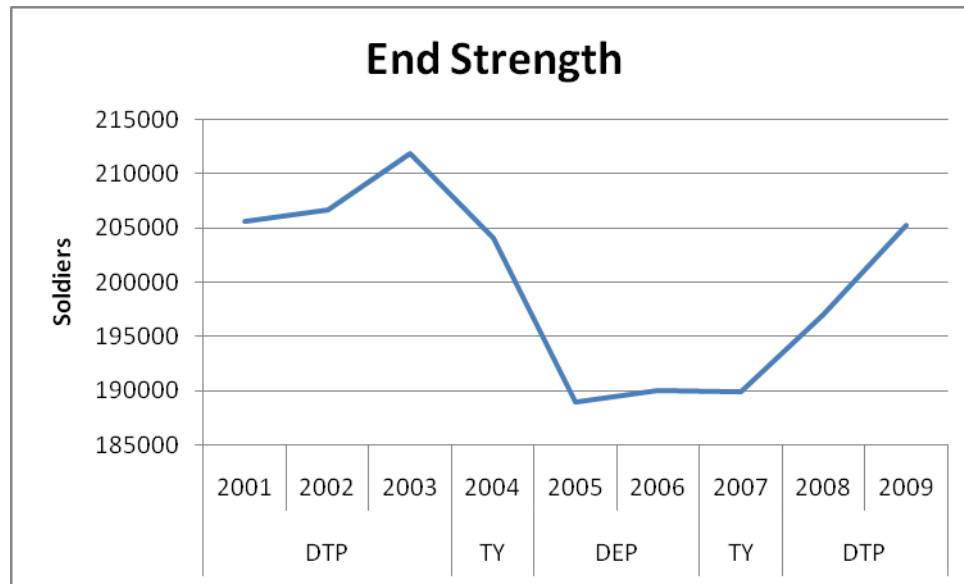


Figure 10. End Strength by Year

Model validation is the process of comparing the simulation behavior to the real system and its behavior (Banks et al. 374). Data collected from the simulation is validated against historical information. Steady-state conditions, after the removal of initial condition bias, are used to validate the simulation. Steady state occurs when the metric of interest becomes stationary about a mean. Historical data is used to validate steady-state results against past USAR end strength. End strength numbers were compared when enlisting solely under the DEP and then again when solely under the DTP.

Historical end strength data is drawn from FY 2001-FY 2009. During FY 2001-FY 2003 and FY 2008-FY 2009 the USAR enlisted applicants under the DTP. From FY 2005 to FY 2006 the USAR enlisted applicants into the DEP. FY 2004 and FY 2007 were years of transition. These dates are taken into account when verifying the model

under each of the programs. A review of historical data shows that during the years the USAR was using only the DEP, the end strength of the USAR was below the ESO. It was far below the minimum authorized strength authorized by Congress.

Review of this data also shows that during the years the USAR enlisted applicants into the DTP, the USAR end strength rose to and exceeded the maximum authorized by Congress. This can be seen easily in Figure 10. The transition years show the drastic decrease and increase and associated programs used by year. When changing from DTP to DEP, there is a decrease in end strength, and when changing from DEP to DTP, there is an increase.

As seen in Figure 11, when the model is run with all applicants joining the DEP, the end strength reached a steady state with a mean around 192,000 Soldiers. The average end strength numbers for FY 2005 and FY 2006 was approximately 191,900 Soldiers. Thus, when run with all applicants joining the DEP, it closely mirrored actual strength of the USAR when policy dictated all applicants would join the DEP.

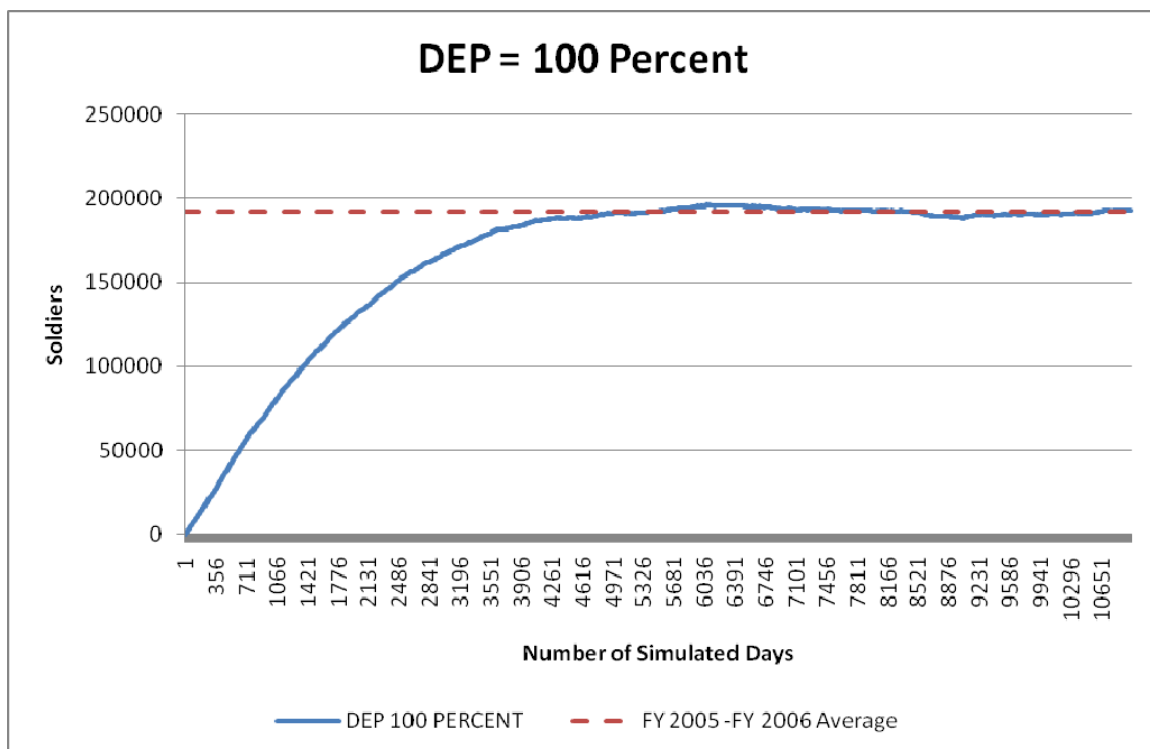


Figure 11. Base Model Run of Simulation Depicting the Reaching of Steady State

To validate the model during the years when the USAR was enlisting into the DTP, the simulation is run with no applicants joining the DEP. End strength during the years the USAR was enlisting under the DTP ranged from an end strength low of 205,297 to an end strength high of 211,890. As can be seen in Figure 12, the end strength reached a steady state around 208,000 Soldiers when the model is run with all OTHER applicants joining the DTP. This is an accurate representation of historical trends.

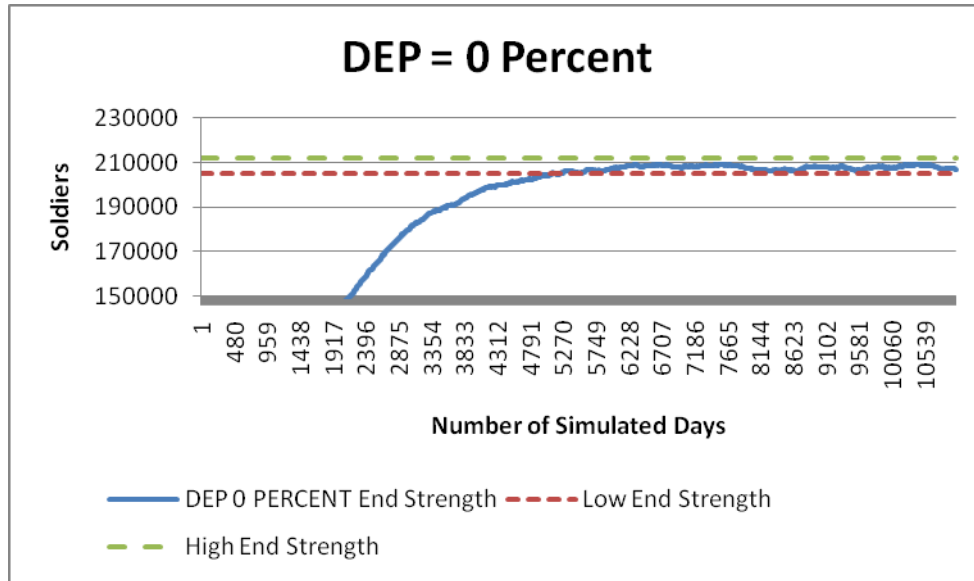


Figure 12. Base Model Run With All Applicants Joining the DTP Depicting the Reaching of Steady State at 209,000 Soldiers

D SCOPE, LIMITATIONS, AND ASSUMPTIONS

This simulation is not intended to account for every detailed aspect of the enlistment process. The scope of this thesis focuses on NPS enlistments into the USAR. It models applicants from the time they enlist to the time they ship to BCT (or become a loss to the USAR).

There are several limitations to the simulation model developed for the thesis research. This model only accounts for changes in the NPS applicants; it does not take into account changes in the PS enlistments. A PS applicant is one who has performed 180 days or more of military service or has graduated from AIT (Chapter II, Section A).

There are 21 variables that are manipulated in this simulation model that are discussed in Chapter III. In addition to the model limitations, there are several assumptions worth noting:

- ESO is represented by average end strength, rather than a single value from 30 September each year.
- Arrivals are consistent throughout the year with no seasonal trends (data driven).
- All MOS are considered equally for enlistment into the DTP or DEP.

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III. EXPERIMENTAL DESIGN

The goal of this thesis is to study the mix of NPS enlisted applicants entering into the USAR in the DTP or DEP. The simulation developed for this study (discussed in Chapter II) is used to study end strength over time for the various policy decisions. End strength is affected by various factors in addition to DTP versus DEP. These factors are included in the simulation and can be manipulated based on current state of affairs or anticipated fluctuation.

Experimental design is used to systematically alter the factors in the simulation model in order to study their impact on the metric of interest (end strength). This chapter details the setup of the experiment, including the inputs of interest and the response variable. The choice of experimental design is also explained.

A. FACTORS AND RESPONSE VARIABLE

1. Factors

The simulation model described in Chapter II has a large number of factors that can be adjusted. There are 21 factors that are manipulated using experimental design. The list of these 21 factors of interest is shown in Table 2. Variable names for each of the factors are listed on the left hand side of the table. During the analysis the factors are analyzed using their variable name (X_1, X_2, \dots, X_{21}). This table can be used as reference.

	FACTORS	RANGES	
		MIN	MAX
X ₁	MEPS ARRIVAL (NUMBER ARRIVALS)	15000	25000
X ₂	CONTRACT RATE (PERCENT)	75%	85%
X ₃	ED LEVEL (PERCENT)	11%	19%
X ₄	TRAIN PATH (PERCENT)	2%	5%
X ₅	JOINS DEP (PERCENT)	10%	90%
X ₆	DEP CIHS ATTRIT RATE (PERCENT)	14%	20%
X ₇	DEP ALT ATTRIT RATE (PERCENT)	13%	26%
X ₈	DEP OTHER ATTRIT RATE (PERCENT)	10%	16%
X ₉	ALT DEP TO BCT (PERCENT)	10%	90%
X ₁₀	CIHS DEP TO BCT (PERCENT)	10%	90%
X ₁₁	OTH DEP TO BCT (PERCENT)	10%	90%
X ₁₂	ALT DEP FAIL TO SHIP (NUMBER OF DAYS)	30	330
X ₁₃	CIHS DEP FAIL TO SHIP (NUMBER OF DAYS)	30	330
X ₁₄	OTH DEP FAIL TO SHIP (NUMBER OF DAYS)	30	330
X ₁₅	ALT DEP TO BCT (NUMBER OF DAYS)	30	330
X ₁₆	CIHS DEP TO BCT (NUMBER OF DAYS)	30	330
X ₁₇	OTH DEP TO BCT (NUMBER OF DAYS)	30	330
X ₁₈	DTP TO BCT (NUMBER OF DAYS)	30	330
X ₁₉	DTP ATTRIT RATE (PERCENT)	9%	15%
X ₂₀	DTP TO FAIL TO SHIP (NUMBER OF DAYS)	30	330
X ₂₁	LENGTH IN DTP IF TRANSFER (NUMBER OF DAYS)	30	180

Table 2. Factors and Ranges

Experimental design requires the specification of values that the input variables can take on. The associated ranges of the values that the 21 factors of interest can take on are also presented in Table 2. The ranges for MEPS Arrival, Education Level, Training Path, and all Attrition Rates were determined based on the analysis of historical data.

The range for Contract Rate is determined by a five percent overage and underage from the USAR contracting goal of 80%. The range selection for the remaining factors, including number of days the applicant is in the DTP or DEP, is based on minimum and maximum time authorized by regulation to remain in either of the programs.

2. Response Variable

The simulation built for this thesis can be used to collect a number of different output variables. Of interest to this thesis work is the end strength output. End strength is used as the sole response variable for the data collection and subsequent analysis.

End strength is important because the USAR is authorized a fixed budget for ESO. An overage of ESO would lead to going over budget. As a result of going over budget another program may suffer because funds would have to be reprogrammed in order to pay personnel. Going over ESO might mean, for example, that funds would have to be removed from equipment acquisition, which would degrade equipment readiness. Alternatively, an underage of ESO would result in decreased readiness.

B THE DESIGN

The experimental design in this thesis is used to study the relationship between the factors in Table 2 and end strength. After running the experiment, linear regression is used to quantify the relationship, if any, between these factors and the end strength. The linear regression model in this thesis considers main effects and two-factor interactions. There are 21 main effects (see Table 2) and 210 two-factor interactions ($21 \text{ choose } 2$).

A factorial design for studying 21 factors would require 2^{21} experiments. This is both infeasible, due to time constraints, and impractical, due to the large amount of data that would be produced. A small number of runs that can efficiently estimate the factors in a linear regression is desirable when the simulation run length is rather long (in this case approximately 3–5 hours per experiment). A better option than the full factorial is the Plackett-Burman (P-B) design (Plackett and Burman 308). The sparsity of effects principle states that only a small portion of the factors are expected to be significant (Montgomery 247), which is why the P-B design chosen is desirable. The P-B design is a

non-regular factorial design useful for screening main effects and two-factor interactions. A non-regular design is one with no full confounding between any two factors of interest. The maximum amount of correlation between any pair of main effects or two-factor interactions is ± 0.33 .

Assuming not all 231 effects (main effects and 2-factor interactions) are significant, 24-run P-B is chosen. The P-B design matrix, in units coded on $[-1,1]$ is shown in Table 3. In addition to the 24 experiments given by the design an additional center point experiment is run. Each row in this design matrix corresponds to a single experiment or run of the simulation.

RUN	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}
1	-1	-1	-1	-1	-1	1	1	1	1	-1	1	-1	1	1	-1	-1	1	1	-1	-1	1
2	-1	-1	-1	-1	1	1	1	1	-1	1	-1	1	1	-1	-1	1	1	-1	-1	1	-1
3	-1	-1	-1	1	1	1	1	-1	1	-1	1	1	-1	-1	1	1	-1	-1	1	-1	1
4	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1	-1	1	1	-1	-1
5	-1	-1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1	-1
6	-1	-1	1	1	1	1	-1	1	-1	1	1	-1	-1	1	1	-1	-1	1	-1	1	-1
7	-1	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1	-1	1	1	-1	-1	1	1	-1
8	-1	1	-1	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1	-1	1	1	-1	-1	1
9	-1	1	-1	1	1	-1	-1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1	1
10	-1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1	-1	1
11	-1	1	1	-1	-1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1	1	1	1
12	-1	1	1	1	1	-1	1	-1	1	1	-1	-1	1	1	-1	-1	1	-1	1	-1	-1
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1	-1	1	1	-1	-1	1	1	-1	-1
15	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1	-1	1	1	-1
16	1	-1	-1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1
17	1	-1	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1	-1	1	1	-1	-1	1	1
18	1	-1	1	-1	1	1	-1	-1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1
19	1	-1	1	1	-1	-1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1	1	1
20	1	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1	-1	1	1
21	1	1	-1	-1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1	1	1	1	1	-1
22	1	1	-1	1	-1	1	1	-1	-1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1	-1
23	1	1	1	-1	1	-1	1	1	-1	-1	1	1	-1	-1	1	-1	1	-1	-1	-1	-1
24	1	1	1	1	-1	1	-1	1	1	-1	-1	1	1	-1	-1	1	-1	1	-1	-1	-1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 3. Plackett-Burman Design Matrix

Note that Table 3 contains the design matrix (the 25 experiments) using coded units. The coded units are on a scale of $[-1, 1]$. The experiments are simulated with actual units, but the analysis is conducted using the coded units in order to directly compare magnitude and direction of all significant main effects or two-factor interactions in unitless quantities. The translation of coded to actual units can be done by relating the low and high levels from Table 2 to -1 and 1 , respectively. As an example, factor X_7 is MEPS Arrival. The low level of MEPS Arrival (-1) corresponds to 15,000 arrivals and the high level ($+1$) corresponds to 25,000 arrivals.

IV. ANALYSIS

Linear regression is used to analyze the data collected after running the experiments explained in Chapter III. The results are discussed throughout this chapter. The JMP software (JMP®) is used to perform all of the data analysis presented in this chapter.

A. LINEAR REGRESSION RESULTS

Stepwise linear regression is used to find the main effects and two-factor interactions that significantly influence end strength. The following hypotheses is tested during the mixed stepwise regression procedure:

$$\begin{aligned} H_o : \beta_i &= 0 \\ H_a : \beta_i &\neq 0 \end{aligned} \quad i = 1, \dots, 232$$

where β_i is the regression coefficient associated with all of the 21 main effects, 210 two-factor interactions, and the intercept (thus there are 232 potentially significant coefficients). Mixed stepwise regression is used with probability to enter and leave set at 0.05.

The results of the stepwise regression procedure are used to generate a fitted linear regression model, using least squares. The resulting equation is:

$$\hat{Y} = 204,726 + 4029X_1 - 3634X_5 + 4514X_1X_5 - 1916X_5X_{15} + 2655X_{20}X_{21}$$

where \hat{Y} = fitted end strength, X_1 =MEPS Arrival, X_5 =Joins DEP, X_{15} =ALT DEP to BCT, X_{20} =DTP to Fail to Ship, and X_{21} =Length in DTP if Transfer. This equation can be used to determine what portion of the population should join the DEP based on projected variable values.

An example of how this equation is used follows: if \hat{Y} is set at ESO, 205,000 and other variable information is set to values found in Table 4, the percent of applicants that should join the DEP can be found.

Factor	Actual Value	Coded Units
X_1	21,000	0.2
X_{15}	90	-0.6
X_{20}	280	0.67
X_{21}	120	0.2

Table 4. Factors, Actual Values, and Coded Units

The coded units are plugged into the variables in the formula and a value is found for X_5 using the steps shown below.

$$\text{Step 1: } 205,000 = 204,726.38 + 4028.9395 \cdot .2 - 3634.08X_5 + 4513.7249 \cdot .2 \cdot X_5 - 1916.062 \cdot X_5 \cdot -0.6 + 2654.986 \cdot .67 \cdot .2$$

$$\text{Step 2: } 87.9359 = -1581.7 \cdot X_5$$

$$\text{Step 3: } 0.056 = X_5$$

$$\text{Step 4: JOINS DEP} = 52.24\%$$

Figure 13 illustrates a good fit, for the regression model, based on the high R^2 and R^2 Adjusted, low mean squared error, and significant analysis of variance F ratio.

Summary of Fit				
RSquare				0.902867
RSquare Adj				0.877306
Root Mean Square Error				2636.135
Mean of Response				204726.4
Observations (or Sum Wgts)				25
Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	1227285658	245457132	35.3216
Error	19	132034978	6949209.4	Prob > F
C. Total	24	1359320636		<.0001*

Figure 13. Screen Shot from JMP® of Summary of Fit and Analysis of Variance

The top three effects, in terms of contribution, are: X_1 , X_5 , and $X_1 \cdot X_5$, are discussed in detail the subsections that follow.

1. DOX Results

a. MEPS Arrivals (X_1)

The fitted regression coefficient for MEPS arrival (X_1) is approximately 4029. The regression coefficient for a main effect is equal to the slope of \hat{Y} as a function of that effect. The effect can be interpreted as saying that: a single unit increase in MEPS Arrival (this translates to a 5,000 increase in actual units as opposed to single units in coded) increases the average yearly end strength by 4029, holding all other factors constant. Note that when the simulation is run with the MEPS Arrivals set at the high level, the USAR achieves the maximum end strength (209,100) authorized by Congress and applicants are denied enlistment. The simulation model can be used to collect data such as number of applicants denied enlistment when the maximum capacity is reached. This turns out to be a function related to the arrival rate at the MEPS.

b. Joins DEP (X_5)

The fitted coefficient for Joins DEP (X_5) is approximately minus 3634. A single unit increase in Joins DEP (40% actual increase) results in a decrease in the average yearly end strength by 3634. This result is expected because when a majority of the applicants are enlisted under the DEP, they are not immediately counted in the end strength.

*c. MEPS Arrival * Joins DEP*

A two-factor interaction, shown in Figure 14, indicates a change in slope for one factor in the presence of another. This two-factor interaction shows that when the MEPS Arrival (X_1) factor is set at the high level, there is little change to the end strength when the Joins DEP (X_5) factor moves from the low level to the high level. It also shows that when the MEPS Arrival (X_1) factor is set at the low level, then the end strength decreases as the Joins DEP (X_5) factor moves from the low level to the high level.

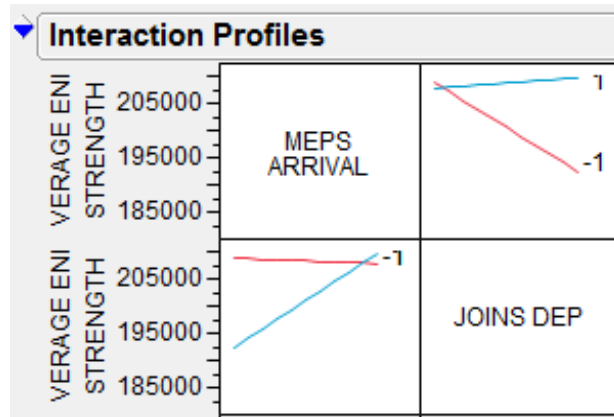


Figure 14. Two-Factor Interactions

2. MEPS Arrival regulation Results

Due to the fact that when the MEPS Arrival (X_1) is at the high level, the end strength immediately rose to the maximum capacity, additional analysis is conducted using a fixed level of MEPS Arrival to determine significant factors. This separate analysis resulted in Contract Rate and Joins DEP as significant main effects. As the Contract Rate increases, so does the USAR end strength; and as the percentage of applicants who Join DEP increases, the USAR end strength decreases.

B. SETTING POLICY BASED ON PERCENTAGE OF APPLICANTS ENTERING THE DEP

When the MEPS Arrival (X_1) factor is at the high level, the end strength numbers increased almost immediately to the maximum capacity of 209,100 Soldiers, regardless of all other factors. Analysis shows there is a definite need for a policy change that allow the DEP and DTP to exist simultaneously. Ultimately, the USAR would like to maintain a steady state around the 205,000 end strength.

Further analysis is conducted holding all factors at nominal levels except Joins DEP (X_5), which is varied from 0%–100% in 10% increments. The USAR is interested in maintaining strength at 205,000 and up to 209,100. Using the results, which are presented in Figure 15, it can be seen that if CIHS, ALT, and 17%–25% of OTHER applicants enlist into the DEP, the end strength falls within the desired levels.

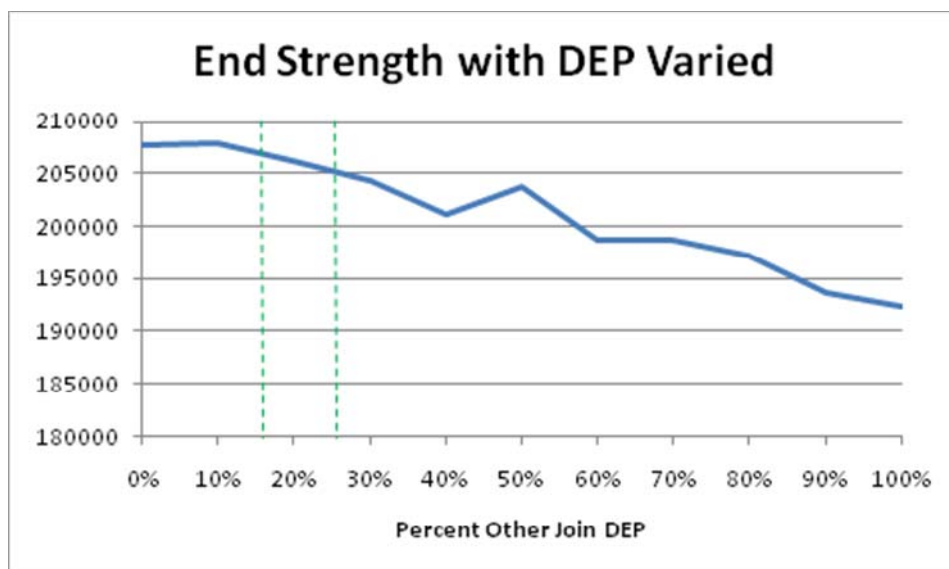


Figure 15. Changes to DEP Percentages Only

If the number of applicants arriving at the MEPS is low, then the percentage allowed into the DEP also needs to be low. The USAR end strength would benefit more if applicants were allowed to enter directly into the DTP. In all of the simulations that the MEPS Arrival (X_1) and DEP percentage were low, the end strength is above 205,000 Soldiers. However, due to the variation of the other factors, 5 of the 6 simulations resulted in a number of applicants denied enlistments. The number of applicants denied enlistment per day ranges from 0.28–4.87 applicants. Figure 16 shows the end strength of Run 1 of the DOX where the MEPS Arrivals and the percentage of OTHER applicants who joined the DEP were both low.

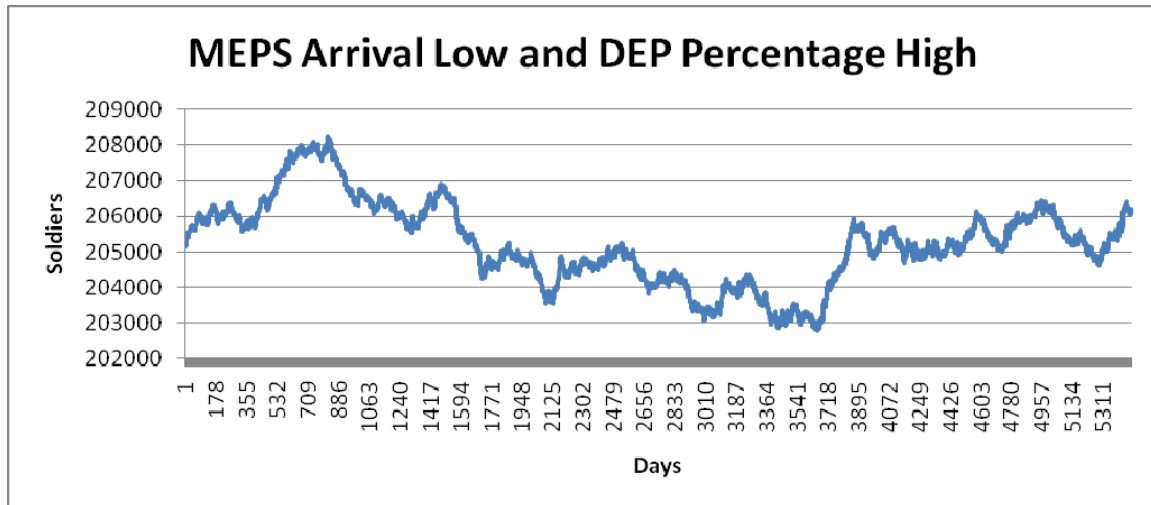


Figure 16. Experimental Run with MEPS Arrival Low and DEP Percentage High

When the number of applicants arriving at the MEPS is low and the percentage of applicants who enter the USAR under the DEP is high, the end strength count never reaches 205,000 Soldiers. Although this simulation leads to no applicants being denied enlistment, it also prevents the USAR from reaching the end strength goal of 205,000 Soldiers. This run also allowed for the highest percentage of DMOSQ Soldiers with roughly 2.97% being non-DMOSQ.

V. CONCLUSIONS AND RECOMMENDATIONS

A. USE OF ARENA MODEL TO IMPLEMENT DIFFERENT POLICIES

A simulation model is developed using Arena Software to study the effects certain factors had on the USAR end strength. This model is broken into two main sections, PS and NPS. The PS portion is developed solely to mirror a PS Soldier from time of enlistment to the time they are a loss to the USAR. The NPS portion of the model is the part that is explored in depth in this thesis.

The simulation model can be used as an analysis tool to evaluate changes to factors of interest. It is currently based on historical data, but can be changed to model current situations, such as accession and attrition rates. It can also be used to evaluate policy changes affecting enlistments to DTP rather than DEP.

Design and analysis of experiments is used to show factors that affect end strength the most are MEPS Arrivals (X_1) and Joins DEP (X_5). These two main effects show that as the MEPS Arrival (X_1) rate increases, so does the end strength of the USAR. When the Joins DEP (X_5) factor increases, the end strength of the USAR decreases. The levels of Joins DEP (X_5) can be adjusted to determine percentage of applicants that should be allowed to join under the DEP to maintain end strength of 205,000 Soldiers, as shown in Chapter IV, Section C for various levels of MEPS Arrivals.

B. FUTURE STUDIES

Additional studies can be conducted in this same area. These areas include expanding the model to account for enlisting into the DTP or DEP based on MOS or recruitment regions, seasonal trends in enlistment, within-year variability of end strength, and the cost associated with each of these programs.

Expanding the model using the various MOS to determine whether the applicant entered under the DTP or DEP could help manage the end strength while helping to filter applicants into the required MOS. MOS that are at a higher level of fill could be set for

enlistees to only join the DEP, thus stabilizing that specific MOS fill. Conversely, MOS that are at a lower level of fill could have Soldiers enlist directly into the DTP in order to count that as an immediate gain to the USAR.

Filtering enlistments into the DTP or DEP based on region of recruitment may also prove to be beneficial. Should there be one region that has a higher level of fill than other regions, then enlistments in that region could be set to DEP only. This would allow the fill for that region to stabilize. The other regions with a lower level of fill could in turn be set to DTP only, thus counting enlistments as immediate gains and stabilizing those regions' strength.

Soldiers in the DTP are allowed to attend and get paid for their attendance at the monthly drills. This incurs a cost to the USAR that could be avoided if these Soldiers had enlisted into the DEP. Paying Soldiers prior to BCT is expensive because these Soldiers are not trained to do their job and there are restrictions on duties they are allowed to perform. A detailed cost analysis should be done to assess the monetary impact of the two enlistment programs on the USAR.

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